Research Reactor Decommissioning Planning—It is Never Too Early to Start

R. S. Eby; (CH2M HILL) [1]
Dr. N. Hertel; (Georgia Institute of Technology)
Contributing Authors: C.Buttram; P. Ervin; L.Lundberg; S. Marske; (CH2M HILL)

Safety Analysis, Licensing & Decommissioning Session 1
International Group on Research Reactors--9
March 24-28, 2003
Sydney, Australia

Abstract
Whether an organization is in the process of designing, constructing or operating nuclear research reactors, past experiences prove it is never too early to start planning for the eventual decontamination, dismantlement and decommissioning (DD&D) of the reactor. If one waits until writing the Decommissioning Plan to seriously think about the DD&D activities, they have lost a key opportunity to be able to efficiently and effectively carry out the DD&D activities and will end up spending large sums of unnecessary funds during the DD&D. This paper will review all phases of research reactor decommissioning from characterization through planning, to eventual DD&D and license termination and highlight areas where early planning can significantly reduce the financial, safety and schedule risks associated with the DD&D activities.

CH2M HILL served as the Executive Engineer for the Georgia Institute of Technology and the State of Georgia to oversee the successful DD&D of their tank type research reactor. CH2M HILL is currently serving as the DD&D contractor for the University of Virginia pool type UVAR and the low power CAVALIER research reactors and as the characterization and Decommissioning Planning contractor for the University of Michigan Ford Nuclear Reactor. Through these activities, an array of lessons learned have been compiled that will prove invaluable to the research reactor owner when they eventually face the DD&D challenge.

As an example, in almost every case CH2M HILL has been involved in reactor DD&D, less than adequate up-front characterization has significantly impacted the ultimate DD&D process cost and schedule. Due to regulatory reasons, intrusive characterization may not always be possible prior to DD&D. However, a thorough understanding of the materials of construction and the quantities of additives or impurities present in those materials; e.g., cobalt in stainless steel, rare earth elements or chlorine in graphite, etc. can provide a profound advantage in predicting activation products that may develop during reactor operations. Mathematical modeling can be effective in predicting the extent of activation. These activation products can significantly impact DD&D activities; such as, DD&D worker dose received, waste handling and disposal plans, and design of deconstruction methods. Also comprehensive documentation via photographs and video, strict configuration control on as-built drawings during construction and operations can reduce future DD&D cost if these are made available during the DD&D bid and proposal phase. This paper will also address what can be done during the characterization phase and describe specific tools and methodology that exist for DD&D activities to improve efficiency and reduce cost of the DD&D project to ultimately achieve license termination and free release of the site.

---

[1] Speaker: Robert S. Eby, Vice-President Nuclear Services and Systems, CH2M HILL, 151 Lafayette Dr, Suite 110, Oak Ridge, Tennessee, 37830
Other Authors Addresses:
Dr Nolan Hertel, Director, Neely Nuclear Research Center, Georgia Institute of Technology, 900 Atlantic Dr, Atlanta, ,GA 30332
C. Buttram, P. Ervin, and L. Lundberg (same address as Eby)
S. G. Marske, CH2M HILL Hanford Inc., 3190 George Washington Way, Richland, WA 99352

Introduction

As Dr. John McKeown stated in a recent presentation to the International Atomic Energy Agency (IAEA), "the technical complexity of decommissioning a nuclear reactor is made enormously more difficult by having to meet the safety standards of the 21st Century – nearly 50 years after the plant was constructed."[2] The decommissioning of research reactors can actually present a more complex task than the DD&D of a nuclear power plant. Research reactor designers, operators and cleanup specialists must recognize that the intent of these reactor operations was for conducting research and not for providing, high-online efficient operations under a set of standard operating conditions. Few reactors were built from a standard design, but more so as a prototype to investigate a particular design or to carry out a specific set of experiments. Ease of decommissioning was not a design criterion, making the process of decommissioning these plants more challenging than it needed to be. That being said, it is important to recognize that deviation and variation then is the norm and conditions one might expect during DD&D may very well not be what actually is encountered. In other words, when executing the DD&D to achieve unrestricted release of a research reactor facility, expect the unexpected. While it is impossible to predict all eventual DD&D scenarios, there are actions that can be taken throughout the life cycle of the reactor, from the design phase through decommissioning to minimize the unexpected and to subsequently reduce cost and increase the safety of the decommissioning task.

Over the past 4 years, CH2M HILL has participated in every aspect of nuclear research reactor decommissioning except for fuel removal, including initial reactor characterization, decommissioning planning, managing and overseeing decommissioning contractors, performance of reactor DD&D and license termination. Through these activities, we have identified numerous practices research reactor personnel can implement during the various stages of design, construction, operations, shutdown, and DD&D which can significantly minimize financial, deconstruction, health and safety, and schedule issues associated with the eventual decommissioning. ALARA, As Low As Reasonably Achievable, does not only address radiological dose factors, but also includes economic aspects as well. The recommendations presented are positive ALARA principles and will subsequently reduce the cost to achieve license termination and unrestricted release of the site. This paper will explore some of those activities and recommend specific courses of action during the research reactor operations.

Actions During the Research Reactor Design/Build Phase

During a time in the design/build cycle of a research reactor, when the eventual DD&D is furthest from a reactor owner's mind, the reactor owner has probably the most important opportunity to significantly impact future decommissioning. First and foremost, if possible at this stage of a reactor's life cycle, consider what organizational residual liability is desired following DD&D; e.g, manage to an unrestricted release criteria, maintain as an industrial use facility, continue as a radiological research facility, etc. Typically, most will desire to release the site for unrestricted use; however that is not always the case, and the decision can have significant impact on how the reactor will be designed, built and operated.

Low cost actions taken during this phase toward the desired end point can reap huge rewards by cost avoidance during the DD&D activities. For example, particular attention should be paid to the proximity of the reactor structure to concrete surfaces, the potential for neutron streaming through open channels, the materials of construction, the use and location of embedded pipes, and the ability to survey, provide for leak detection, and remove embedded pipe.

The choice of materials during construction is an obvious issue. Where possible, minimize the use of easily activated materials. For example, use aluminum or other non-activating materials for all components of the beam port tube and inserts. Our work has noticed situations where aluminum would be the primary metal, however, bolts may be made of stainless steel. This

---

[2] Dr. John McKeown, Decommissioning—The Worldwide Challenge, International Atomic Energy Agency Forum, September 17, 2002.

resulted in the handling of extremely radioactive components during the DD&D phase. Care should be taken in purifying graphite prior to installation. Many graphite materials are purified thermally leaving impurities such as rare earth elements to become activated. At the Georgia Tech Research Reactor, we were unable to dispose of the graphite at a low level radioactive disposal site because of the presence of a Europium-152 and -154. (Figure 1) This resulted in a measurable increase in the disposal cost as well as significant increase in the exposure to the workers when manually removing the keyed graphite stringers. Other graphite materials are purified using halogenated compounds which can present disposal issues of its own from the presence of chlorine-36**.** Ideally, a trace element analyses of construction materials to the ppm level for known activation targets would be valuable during the construction phase. This can minimize surprises during the DD&D activity.

Figure 1. Graphite stringers were found to contain activated Europium because the graphite was not purified to remove the rare earth elements prior to installation.

One of the most important and inexpensive activities is to maintain an accurate set of as-built drawings and document via photographs every phase of construction. With the ease of digital photography, one should not spare on the number of photographs that are taken during construction as well as when process changes are implemented. In the world of decommissioning a picture can be worth far more than a thousand words. There is no substitute for up-to-date photographs.

Particular care should be made to minimize embedded and underground pipes and to provide for ease of survey for those that are placed underground or are embedded in concrete. Consideration should be given to configure for removal or ease of flushing and surveying all lines potentially carrying radioactive fluids; e.g, double sleeve piping. Double sleeved piping easily allows for leak detection and replacement if found to be leaking and cost less than digging up the contaminated pipe. By minimizing the quantity of embedded pipe, the expense to double sleeve and leak detection can be kept to a minimum and should prove cost effective during the decommissioning phase.

Minor modifications can be implemented during the design and construction phase to allow the neutron flux to be measured at various places in the bioshield during operations. By knowing the flux, models can predict with a higher degree of accuracy the depth of concrete activation. This valuable data typically can not be otherwise obtained without intrusive characterization—usually an option not allowed by the regulatory agency until a Decommissioning Plan has been approved. Determining the levels of activation in the reactor bioshield, after the Decommissioning Plan has been approved or worse yet, during the decommissioning, is typically too late to take economic advantage during a bid and proposal phase. At the Omega West Reactor at Los Alamos, small holes were included in the bioshield to measure the neutron flux levels at various locations in the bioshield during operation

Actions During the Operation Phase

During the operations phase, maintaining contamination control is probably the most important factor to reduce eventual DD&D costs. Effective operator and maintenance training programs are the key to preventing the spread of contamination. Frequent and adequate radiological monitoring and immediate decontamination of identified hot spots are effective ways to reduce the overall spread of contamination.

Periodic sampling of materials can also identify neutron streaming where materials are becoming activated. When these areas are identified effective neutron absorbers or shield may prevent continued activation and minimize the eventual radiological waste generated that must be disposed at much higher disposal rates.

Configuration control on drawings and the use of photographs as reactor systems are changed is crucial to avoid expensive change orders during the DD&D. Maintaining good records of operations that can be used in modeling the extent of activation is an inexpensive activity that will provide useful information in developing the DD&D plans. It is recommended experimental data be retained that may provide a check on estimated neutron intensities around the core.

Tracking neutron exposure variations between multiple neutron exposure pathways, such as beam ports, will provide insight where radiological materials may be present. Specific experiments; e.g., activation foils in the beam ports, can also provide neutron flux information as a byproduct to define activation levels of the permanent structures.

Actions During Reactor Decommissioning Characterization and Planning Phase

The more one knows about the state of the reactor and surrounding bioshield, the fewer surprises that will be encountered during decommissioning. Prior to performing any characterization or planning, verify the residual endpoint the owner is looking for; e.g., unrestricted release, industrial use, etc. This decision will significantly impact the level of characterization, planning and ultimate DD&D activity.

The importance of a thorough characterization cannot be understated, particularly if you plan to fix price bid the DD&D project. Do not fix-price bid an uncharacterized facility. It will only result in costly change orders and significant frustration in managing the DD&D effort. The facility should be as intrusively characterized as the regulators will allow prior to Decommissioning Planning (Figure 2).

Write a flexible Decommissioning Plan (DP) that delivers the right end product without prescriptive details. Providing too much detail locks the owner into a set method for DD&D. As an example, one project we worked on described a process by which the reactor bioshield would be core-bored to remove only the radioactive materials leaving a free-standing unrestricted released monolith. Because this was in the approved Decommissioning Plan, the subcontractor was restricted to develop a process and procedures to leave the monolith free standing while removing the radioactive material. This was very inefficient. Had the DP been approved via a "Decommissioning Order", in the United States any changes to this DP would require lengthy NRC review and approval. Since it was approved via a License Amendment, this allowed the license holder, the University, to utilize the 10 CFR 50.59 process and evaluate the impacts of revising the DP against the safety envelope without the NRC approval. Once the evaluation was completed, it was easy to see that by completely removing the bioshield, the decommissioning could be completed more safely and less residual radioactivity would be present. Still, even the need to use the 10 CFR 50.59 process could have been avoided had the writers of the DP been less prescriptive. In the United States, the 10 CFR 50.59 process can be a very valuable DD&D tool. It allows the license holder to evaluate actions and take appropriate steps so long as the safety envelope is not reduced. It is strongly recommended that one work with their regulator to see if these opportunities are present prior to the development of the DP.

The DD&D job is not complete until the governing regulatory agency provides the license termination document. It is important to have this agency participate from the beginning of DD&D planning throughout the decommissioning activities. It is highly recommended regular reports on DD&D status be sent to the regulatory agency as well as invitations to observe or witness special D&D actions such as removing the reactor vessel. Do not hesitate to gain concurrence on strategies and plans. Even if the regulatory agency will not provide written concurrence, at minimum they will be informed on the activities and the degree to which the actions were executed toward the final end product. Let the agency comment on any strategies taken that differ from the approved Decommissioning Plan. Try to understand their concerns such that when they return to perform the final site status survey, there will be no surprises. Throughout the DD&D of the Georgia Tech Research Reactor, regular communications were maintained with the NRC resident inspector and project manager. This action significantly helped as the University moved toward license termination.

Use proven models to predict the extent of activation. This is particularly important if intrusive characterization is not allowed. Utilizing data obtained during the operation of the reactor helps model reactor activation products to reduce the risk of encountering unknowns. As more reactors go through DD&D, these models can be refined and the prediction confidence will be significantly increased.

Figure 2. Intrusive sampling is best for providing meaningful characterization data about activation products in the bioshield. Modeling tools and operational data can also provide valuable information in characterizing the DD&D project.

Actions During Reactor Decommissioning Phase

Once all the planning has been accomplished, there are still activities that can be performed during the DD&D to significantly reduce cost. Operating in a safe and environmentally compliant manner will go a long way in ensuring maximum productivity and preventing future legacy issues. Identify and implement "As Low As Reasonably Achievable (ALARA) principles. ALARA activities not only make sense from a Health, Safety, & Environmental protection perspective, they are also good business sense activities to improve productivity. At the University of Virginia, we employed underwater divers (Figure 3) in the pool which reduced the total worker dose for removing activated components from a predicted value of 1800 mRem to less than 60 mRem. The work was also completed in a much reduced time frame. The action took 7 days with divers vs. 35 expected days from using cumbersome long-handled tools from the side of the pool.

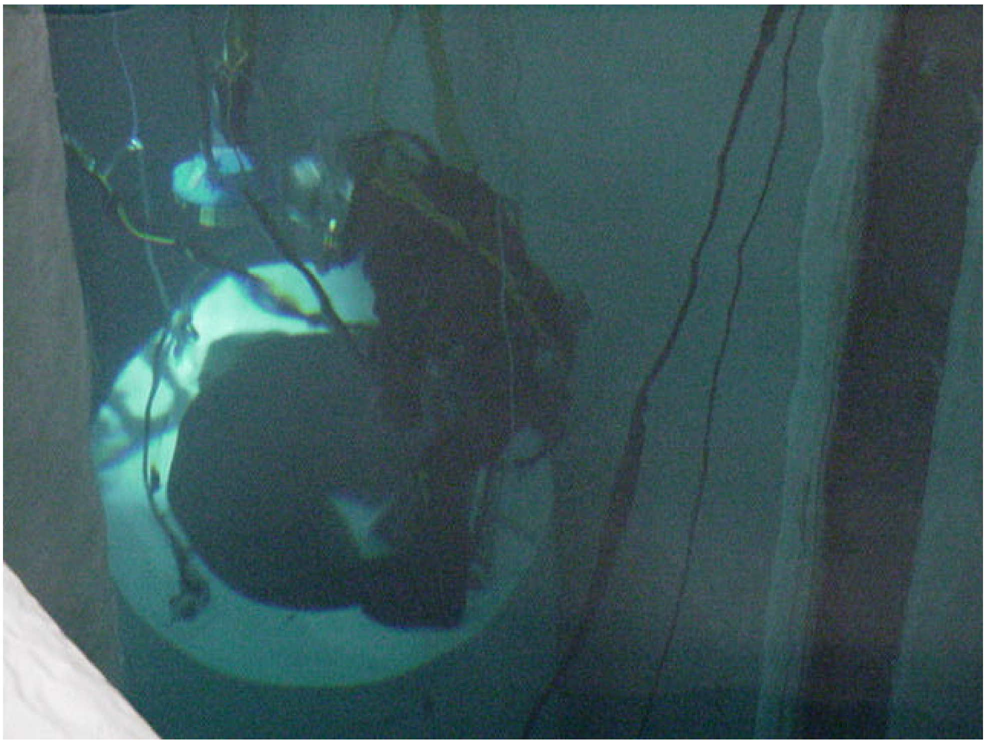

Figure 3. Using underwater divers to collect and isolate the activated components in the reactor pool significantly reduced the worker exposure and the client cost during the DD&D activity. (Photo courtesy KK Allen)

Minimize the spread of contamination. Localized tenting can be a low-cost effective technique for accomplishing this goal; however, as we found at Georgia Tech, temperatures inside enclosed tents can become very uncomfortable, particularly if work is done in a humid environment where machines such as hoe-rams are operating with little or no ventilation in order to prevent spread of contamination. Sometimes, one has to trade-off factors such as comfort for controlling the spread of contamination. If this is the case, however, be sure to carefully monitor the personnel for dehydration and overheating, particularly if the workers are in full-faced respirators and protective clothing.

Free release as much material as possible and minimize waste generation. Once again, trade-offs are important. Sometimes it is more costly to survey complex equipment for free release than it is to quickly remove and ship the material to a low-level disposal site. Transportation and disposal costs must be traded against segregation and survey costs.

Always be ready for the unexpected. Recognize that research reactors are operated differently than commercial power reactors and as such will likely have unique activation products in unexpected environments, contamination, and other changes not seen in reactors under commercial controls. Also, recognize that the major health and safety issues are greatest concern are most likely to be industrial issues, not radiological. Never lose sight of the “Safety First” principle. Job Hazards Analysis (JHAs) and tool box safety meetings are effective in planning for the unknown. These are very important activities to incorporate during the DD&D phase of the work and will minimize costly safety issues and work stoppages during the effort. Time is money and using equipment that minimizes time in radiological control zones can significantly reduce the overall cost of decontamination. Use efficient, state-of-the art high technology equipment, such as hydrolasing, where practical. Handheld portable and fixed gamma ray spectroscopy are effective instruments in identifying radioactive components and levels of contamination. Our experience is that the work productivity in a radiological zone may be as much as a factor of 4 less than working outside these zones. If you can reduce your radiological zones by free releasing areas early, you may incur significant improvements in the decommissioning schedule.

As presented earlier, in the United States the 10 CFR 50.59 is a regulation that allows the license holder to self-evaluate if changes to the NRC approved Decommissioning Plan can be made without affecting the safety-envelope (Figure 4). Effectively using this avenue can permit major cost and time savings during the DD&D phase as inevitable changes will arise during the DD&D activity. The whole decision process takes just a few days as compared to literally months for these decisions to go back to the NRC for approval.

Figure 4. Georgia Tech used the 10 CFR 50.59 process to evaluate the safety impacts for dismantling the reactor bioshield instead of only removing the radioactive components. This action saved considerable time and money in the overall decommissioning process.

Do not use hotspot smears to define the non-detectable isotope footprint; e.g., tritium, and iron-55 for the purpose of calculating Site Specific Guideline Levels (SPGLs) to address the non-detectable isotopes in determining release standards. At the heavy water moderated, heavy water cooled Georgia Tech reactor, more than 90% of the total contamination was due to tritium. To be conservative, the Decommissioning Contractor took smear samples of known heavy water spill locations to assess overall tritium contamination and then calculated SPGL decontamination levels for the other isotopes. This resulted in overly conservative SPGL's for the alpha and beta/gamma emitting isotopes and drove the required levels to near background measurements for free releasing the site. Instead of this approach, utilize a justifiable, statistical basis in determining the number and location of the samples for determining the difficult to measure isotope levels within the facility.

Work closely with regulatory agencies throughout the process. Achieving the final goal of license termination is only obtainable if you satisfy the regulatory agency. Therefore, do not hesitate to provide reports to them, ask questions of them, or invite their observers to view the performance of critical decontamination activities. Having them present to respond to specific questions when the actions are being performed can be much less costly than having to perform rework after the equipment has been removed from the area or the site. With the regulators, schedule in advance the final release survey and confirmatory survey. Typically, in the United States, the NRC needs at least 3 months notice to put your site on their validation confirmation travel schedule. When the regulatory agency performs their confirmatory surveys, it is recommended you participate in the survey. If any hot spots are identified, take immediate action to clean up while the inspector is still in the area and can verify cleanup.

Summary

The life-cycle of every nuclear reactor covers planning, designing, licensing, constructing, operating and DD&D. Each phase is integral to the success of every other phase, and every succeeding phase is implements a component of the previous phases. DD&D is no exception. It is not uncommon for the planning phase to consider design, licensing, construction and operation, and likewise throughout the process; however, previously little effort has been placed early on to how the DD&D phase fits into the earlier phases. Too many times, it is DD&D is the last consideration given to the life cycle of a nuclear reactor as is said in the United States, it is the "tail that wags the dog". The owner does not consider the impact of DD&D on the overall project financials and success until it is too late to impact the process. This paper has provided action items that reactor owners should place a high priority on considering throughout the reactor life cycle, if the owner desires to minimize the cost and risk impact of the DD&D phase.

Referring once again to John McKeown[2] talk to the IAEA General Conference Scientific Forum in September, 2002, McKeown stated, "Start decommissioning whilst the facilities are in good condition, solve tomorrow's problems today… manage waste to meet existing and final disposal requirements…learn from the experience of others…where possible use commercially available equipment or materials rather than develop new ones…recruit and maintain people with necessary skills and expertise…earn public trust by laying out plans early…and to spend wisely early and benefit later".

To McKeown's summary, these authors add to start the process even earlier; i.e., before the facilities are built. The earlier the owner begins to think about decommissioning, even as early as in the reactor design phase, the lower the owner's cost to decontaminate, dismantle and decommission will be and the fewer surprises and headaches they will encounter in executing this vital stage in the life cycle of a nuclear reactor.